

Presymmetry beyond the Standard Model

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We go beyond the Standard Model guided by presymmetry, the discrete electroweak quark-lepton symmetry hidden by topological effects which explain quark fractional charges as in condense matter physics. Partners of the particles of the Standard Model and the discrete symmetry associated with this partnership appear as manifestations of a residual presymmetry and its extension from matter to forces. This duplication of the spectrum of the Standard Model keeps spin and comes nondegenerated about the TeV scale.

1. Introduction

The notion of presymmetry was introduced by Ekstein [1, 2] in the sixties to deal with the survival of some results of space-time symmetry when this is broken by an external field. It is a pre-dynamical symmetry which becomes only partially broken by the dynamics with a residual presymmetry. We have used the same term in the Standard Model (SM) of elementary particle physics and done analogies to the idea of Ekstein [3, 4].

In the SM, presymmetry becomes a symmetry which extends the quark-lepton symmetry from weak to electromagnetic interactions. It is a hidden charge symmetry, so hidden that it can be eliminated by using the Occam's razor principle which states that entities should not be multiplied unnecessary, unless that some results of the charge symmetry survive in the new physics beyond the SM [4].

This work has been organized as follows. We start by presenting the quark-lepton charge symmetry that has motivated the research (Section 2). Next, we state hypotheses to account for this charge symmetry (Section 3). We describe the approach, which adds to the SM the new hidden states of prequarks and preleptons, and the associated presymmetry (Section 4). The problem of gauge anomaly is addressed (Section 5). Motivations to go beyond the SM with presymmetry are given, emphasizing a duplication of the SM particles to have a residual presymmetry in the sense of Ekstein (Section 6). And we finish with some conclusions based on results (Section 7).

2. Quark-Lepton Charge Symmetry

At the level of the SM, presented in Figure 1, quarks and leptons are quite different in the strong sector: quarks come in triplets while leptons do in singlets of the color group. However, they have similar properties in the weak sector, a fact known as quark-lepton symmetry. Regarding hypercharge, values appear very different and no charge symmetry is readily seen. But, a closer inspection shows that there is something underlying these values, a hidden charge

Fermions	SU(3) _c	SU(2) _L	U(1) _Y
$\begin{pmatrix} u_{aL} \\ d_{aL} \end{pmatrix}$	3	2	1/3
u_{aR}	3	1	4/3
d_{aR}	3	1	-2/3
$\begin{pmatrix} \nu_{aL} \\ e_{aL} \end{pmatrix}$	1	2	-1
ν_{aR}	1	1	0
e_{aR}	1	1	-2

Figure 1: Quark and lepton assignments to representations of gauge groups of the SM, where a denotes the generation index.

$Y(u_{aL}) = 1/3 = -1 + 4/3 = Y(\nu_{aL}) - 4/3 \text{ (3B-L)}(\nu_{aL})$
$Y(u_{aR}) = 4/3 = 0 + 4/3 = Y(\nu_{aR}) - 4/3 \text{ (3B-L)}(\nu_{aR})$
$Y(d_{aL}) = 1/3 = -1 + 4/3 = Y(e_{aL}) - 4/3 \text{ (3B-L)}(e_{aL})$
$Y(d_{aR}) = -2/3 = -2 + 4/3 = Y(e_{aR}) - 4/3 \text{ (3B-L)}(e_{aR})$

$Y(\nu_{aL}) = -1 = 1/3 - 4/3 = Y(u_{aL}) - 4/3 \text{ (3B-L)}(u_{aL})$
$Y(\nu_{aR}) = 0 = 4/3 - 4/3 = Y(u_{aR}) - 4/3 \text{ (3B-L)}(u_{aR})$
$Y(e_{aL}) = -1 = 1/3 - 4/3 = Y(d_{aL}) - 4/3 \text{ (3B-L)}(d_{aL})$
$Y(e_{aR}) = -2 = -2/3 - 4/3 = Y(d_{aR}) - 4/3 \text{ (3B-L)}(d_{aR})$

Figure 2: Quark-lepton charge symmetry.

symmetry which extends the weak connection.

The one-to-one correspondence between quark and lepton hypercharges is shown in Figure 2. The fractional hypercharge of a quark is that of its lepton weak partner plus a global fractional value which is independent of flavor and handness. Actually, it is a fraction of the lepton number of its partner. In a similar way, the entire hypercharge of a lepton is that of its quark partner plus a global fractional value which is a fraction of the baryon number times the number of colors. Although this global fractional part depends upon the hypercharge normalization, the quark-lepton charge symmetry is still present.

The crucial question is whether these charge relations are real or accidental. Our hypothesis is that this quark-lepton charge symmetry is real and that the global fractional piece of charge has a topological character independently of the normalization used for hypercharge [3].

3. Statement of Principles

Formally, our assumptions are described in these two principles [3]:

- Principle of electroweak quark-lepton symmetry: *There exists a hidden discrete Z_2 symmetry in the electroweak interactions of quarks and leptons.*
- Principle of weak topological-charge confinement: *Observable particles have no weak topological charge.*

The principle of weak topological-charge confinement is secondary to that of gauge confinement in the sense that electroweak forces by themselves cannot lead to actual confinement of topologically nontrivial particles.

We distinguish the electroweak-symmetric topological quarks and topological leptons of our approach from the topologically trivial quarks and leptons of the SM. The assignments of topological quarks to the gauge groups of the SM are as usual quarks in Figure 1, whereas those of topological leptons are defined below. Topological quarks and topological leptons of fractional charge do have hidden charge structures and nontrivial topology. They are not mass eigenstates and have associated weak gauge fields with vacuum states having nonzero topological charge. Topological quarks and topological leptons have a topological bookkeeping Z_3 charge, with +1 assigned to all of them. The 3 of this modulo charge in topological quarks and topological leptons is due to the number of colors and the number of generations [3], respectively, though topological leptons do not confine. When the bookkeeping charge is 3, the set has no topological charge and trivial topology. Three topological quarks are equivalent to three standard quarks.

4. Topological Quarks and Leptons

To describe the charge structure of topological quarks, we introduce the new states of *prequarks* with integer charge and trivial topology, as in leptons. Similarly, we introduce topological leptons or *preleptons*, with fractional charge and nontrivial topology, just as in topological quarks [3]. We denote prequarks and preleptons by \hat{q} and $\hat{\ell}$, respectively.

Prequark	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
$\begin{pmatrix} \hat{u}_{aL} \\ \hat{d}_{aL} \end{pmatrix}$	3	2	-1
\hat{u}_{aR}	3	1	0
\hat{d}_{aR}	3	1	-2

Prelepton	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
$\begin{pmatrix} \hat{\nu}_{aL} \\ \hat{e}_{aL} \end{pmatrix}$	1	2	1/3
$\hat{\nu}_{aR}$	1	1	4/3
\hat{e}_{aR}	1	1	-2/3

Figure 3: Assignments of prequarks and preleptons to gauge groups of the SM.

Charge dequantization in topological quarks and preleptons is according to Figure 2 and has the following form:

$$Y(q) = Y(\hat{q}) - \frac{4}{3}(B - 3L)(\hat{q}),$$

$$Y(\ell) = Y(\hat{\ell}) - \frac{4}{3}(B - 3L)(\hat{\ell}). \quad (1)$$

The lepton number is times 3 because prequarks are the ones that now have integer charge and preleptons now have fractional charge.

Assignments of prequarks and preleptons to gauge groups of the SM are shown in Figure 3 and charge connections with leptons and topological quarks are given by the following constraints consistent with relations in Figure 2:

$$Y(\hat{q}) = Y(\ell),$$

$$Y(\hat{\ell}) = Y(q),$$

$$(B - 3L)(\hat{q}) = (3B - L)(\ell) = -(3B - L)(q),$$

$$(B - 3L)(\hat{\ell}) = (3B - L)(q) = -(3B - L)(\ell). \quad (2)$$

The additive quantum numbers of prequarks and preleptons are listed in Figures 4 and 5, respectively. We note that $B - L$ becomes a good quantum number between prequarks and leptons, and between preleptons and topological quarks [3].

This is a conservative model in the sense that usual quarks and leptons are considered elementary with no charge structure. Charge structure is in topological quarks and preleptons. There is symmetry between topological quarks and preleptons, as between prequarks and leptons.

Prequark	\hat{u}	\hat{d}	\hat{s}	\hat{c}	\hat{b}	\hat{t}
B (baryon number)	-1	-1	-1	-1	-1	-1
Q (electric charge)	0	-1	-1	0	-1	0
I_z (isospin z-component)	1/2	-1/2	0	0	0	0
S (strangeness)	0	0	-1	0	0	0
C (charm)	0	0	0	1	0	0
B^* (bottomness)	0	0	0	0	-1	0
T (topness)	0	0	0	0	0	1

$$Q = I_z + \frac{1}{2}(B + S + C + B^* + T)$$

Figure 4: Additive quantum numbers of prequarks.

Prelepton	$\hat{\nu}_e$	\hat{e}	$\hat{\nu}_\mu$	$\hat{\mu}$	$\hat{\nu}_\tau$	$\hat{\tau}$
L (lepton number)	-1/3	-1/3	-1/3	-1/3	-1/3	-1/3
Q (electric charge)	2/3	-1/3	2/3	-1/3	2/3	-1/3
L_{ν_e} (electron neutrino)	1	0	0	0	0	0
L_e (electroness)	0	-1	0	0	0	0
L_{ν_μ} (muon neutrino)	0	0	1	0	0	0
L_μ (muoness)	0	0	0	-1	0	0
L_{ν_τ} (tau neutrino)	0	0	0	0	1	0
L_τ (tauness)	0	0	0	0	0	-1

$$Q = \frac{1}{2}(-L + L_e + L_{\nu_e} + L_\mu + L_{\nu_\mu} + L_\tau + L_{\nu_\tau})$$

Figure 5: Additive quantum numbers of preleptons.

Presymmetry is the statement of charge symmetry between topological quarks and preleptons, and between leptons and prequarks. There is invariance in the bare electroweak Lagrangian under the flavor transformation given in Figure 6, with no change on gauge and Higgs fields.

5. Gauge Anomaly Cancellation

There is, however, a problem: the entire hypercharge of prequarks and the fractional hypercharge of preleptons lead to gauge anomalies. Here it is shown the anomaly in the scenario of prequarks. It is found (see [3]) that the $U(1)_Y$ gauge current of prequarks and leptons

$$\begin{aligned} \hat{J}_Y^\mu = & \bar{q}_{aL} \gamma^\mu \frac{Y}{2} \hat{q}_{aL} + \bar{q}_{aR} \gamma^\mu \frac{Y}{2} \hat{q}_{aR} \\ & + \bar{\ell}_{aL} \gamma^\mu \frac{Y}{2} \ell_{aL} + \bar{\ell}_{aR} \gamma^\mu \frac{Y}{2} \ell_{aR}, \end{aligned} \quad (3)$$

exhibits the $U(1)_Y[SU(2)_L]^2$ and $[U(1)_Y]^3$ anomalies according to

Quark-prelepton:

$$\begin{aligned} u_{aL}^i & \leftrightarrow \hat{\nu}_{aL}^i & u_{aR}^i & \leftrightarrow \hat{\nu}_{aR}^i \\ d_{aL}^i & \leftrightarrow \hat{e}_{aL}^i & d_{aR}^i & \leftrightarrow \hat{e}_{aR}^i \end{aligned}$$

Lepton-prequark:

$$\begin{aligned} \nu_{aL} & \leftrightarrow \hat{u}_{aL}^i & \nu_{aR} & \leftrightarrow \hat{u}_{aR}^i \\ e_{aL} & \leftrightarrow \hat{d}_{aL}^i & e_{aR} & \leftrightarrow \hat{d}_{aR}^i \end{aligned}$$

Figure 6: Presymmetry between topological quarks and preleptons, and between leptons and prequarks.

$$\begin{aligned} \partial_\mu \hat{J}_Y^\mu = & -\frac{g^2}{32\pi^2} \left(\sum_{\hat{q}_L \ell_L} \frac{Y}{2} \right) \text{tr } W_{\mu\nu} \tilde{W}^{\mu\nu} \\ & -\frac{g'^2}{48\pi^2} \left(\sum_{\hat{q}_L \ell_L} \frac{Y^3}{2^3} - \sum_{\hat{q}_R \ell_R} \frac{Y^3}{2^3} \right) F_{\mu\nu} \tilde{F}^{\mu\nu}, \end{aligned} \quad (4)$$

where g , g' and $W_{\mu\nu}$, $F_{\mu\nu}$ are the $SU(2)_L$, $U(1)_Y$ couplings and field strengths, respectively, $\tilde{W}^{\mu\nu}$ and similarly $\tilde{F}^{\mu\nu}$ is defined by

$$\tilde{W}_{\mu\nu} = \frac{1}{2} \epsilon_{\mu\nu\lambda\rho} W^{\lambda\rho}, \quad (5)$$

and the hypercharge sums run over all the fermion representations. The anomalies appear because these sums do not vanish.

The anomaly can be written in terms of topological currents as follows:

$$\partial_\mu \hat{J}_Y^\mu = -N_{\hat{q}} \partial_\mu J_T^\mu, \quad (6)$$

where $N_{\hat{q}} = 12N_g$ is the number of left- and right-handed prequarks, N_g denotes the number of generations, and

$$\begin{aligned} J_T^\mu = & \frac{1}{4N_{\hat{q}}} K^\mu \sum_{\hat{q}_L \ell_L} Y \\ & + \frac{1}{16N_{\hat{q}}} L^\mu \left(\sum_{\hat{q}_L \ell_L} Y^3 - \sum_{\hat{q}_R \ell_R} Y^3 \right) \\ = & -\frac{1}{6} K^\mu + \frac{1}{8} L^\mu. \end{aligned} \quad (7)$$

The K^μ and L^μ are the well-known topological currents or Chern-Simons classes related to the $SU(2)_L$

and $U(1)_Y$ gauge groups, respectively. They are given by

$$K^\mu = \frac{g^2}{8\pi^2} \epsilon^{\mu\nu\lambda\rho} \text{tr} \left(W_\nu \partial_\lambda W_\rho - \frac{2}{3} ig W_\nu W_\lambda W_\rho \right),$$

$$L^\mu = \frac{g'^2}{12\pi^2} \epsilon^{\mu\nu\lambda\rho} A_\nu \partial_\lambda A_\rho. \quad (8)$$

The counterterm needed for anomaly cancellation is

$$\Delta\mathcal{L} = g' N_{\hat{q}} J_T^\mu A_\mu. \quad (9)$$

It leads to the anomaly-free, but gauge noninvariant current

$$J_Y^\mu = \hat{J}_Y^\mu + N_{\hat{q}} J_T^\mu, \quad (10)$$

such that

$$\partial_\mu J_Y^\mu = 0. \quad (11)$$

However, the charge of the new current is not conserved because of topological charge. Topological charge resides in the topology of weak gauge fields. As a matter of fact,

$$Q_Y(t) = \int d^3x J_Y^0 = \frac{N_{\hat{q}}}{6} n_W(t), \quad (12)$$

where n_W is the winding number of the gauge transformation of the pure gauge configuration given by

$$n_W(t) = \frac{1}{24\pi^2} \int d^3x \epsilon^{ijk} \text{tr}(\partial_i U U^{-1} \partial_j U U^{-1} \partial_k U U^{-1}). \quad (13)$$

The charge change is

$$\begin{aligned} \Delta Q_Y &= \frac{N_{\hat{q}}}{6} [n_W(t=+\infty) - n_W(t=-\infty)] \\ &= \frac{N_{\hat{q}}}{6} Q_T = \frac{N_{\hat{q}}}{6} Q^{(3)} n, \end{aligned} \quad (14)$$

where

$$Q_T = \int d^4x \partial_\mu K^\mu = \frac{g^2}{16\pi^2} \int d^4x \text{tr}(W_{\mu\nu} \tilde{W}^{\mu\nu}). \quad (15)$$

A Z_3 counting number $Q^{(3)}$ is introduced with the topological charge n , equal to ± 1 for nontrivial topology and 0 for trivial topology, just as if the topological charge were itself a Z_3 charge. It is due to the hypotheses of the model. A consequence of all these is

that each prequark has to change its hypercharge by the same value, a charge shift which can be adjusted to cancel anomalies:

$$Y(\hat{q}) \rightarrow Y(\hat{q}) + \frac{n}{3} Q^{(3)}(\hat{q}) = Y(\hat{q}) - \frac{n}{3} (B - 3L)(\hat{q}). \quad (16)$$

The required value for the topological index is 4, because in such a case we have

$$\sum_{q_L \ell_L} Y = 0, \quad \sum_{q_L \ell_L} Y^3 - \sum_{q_R \ell_R} Y^3 = 0. \quad (17)$$

It is worth noting that the value $n = 4$ of the topological charge does not depend on the relation $Q = T_3 + Y/2$ between electric charge, weak isospin and hypercharge adopted in this work, as remarked in Section 2.

The charge normalization restores gauge invariance, breaks presymmetry between prequarks and leptons and dresses prequarks into fractionally charged topological quarks, consistent with Eq. 1 and our hypotheses concerning the quark-lepton charge symmetry in Figure 2. It is seen that the fractional charge of topological quarks is explained as in condensed matter physics [3]. Now one can define an effective current by

$$\hat{J}_{Y,\text{eff}}^\mu = -\frac{2}{3} [\bar{q}_{aL} \gamma^\mu (B - 3L) \hat{q}_{aL} + \bar{q}_{aR} \gamma^\mu (B - 3L) \hat{q}_{aR}] \quad (18)$$

to absorb topological effects: gauge anomaly cancellation, trivial topology and fractional charge. Thus Eq. (10) takes the gauge-independent form

$$\begin{aligned} J_Y^\mu &= \bar{q}_{aL} \gamma^\mu \frac{Y - 4(B - 3L)/3}{2} \hat{q}_{aL} \\ &\quad + \bar{q}_{aR} \gamma^\mu \frac{Y - 4(B - 3L)/3}{2} \hat{q}_{aR} \\ &\quad + \bar{\ell}_{aL} \gamma^\mu \frac{Y}{2} \ell_{aL} + \bar{\ell}_{aR} \gamma^\mu \frac{Y}{2} \ell_{aR}. \end{aligned} \quad (19)$$

At this point, prequarks can be identified as quarks of fractional charge and trivial topology: $\hat{q} \rightarrow q$. Connection between topological quarks and standard quarks is nonperturbative.

Cancellation of gauge anomalies in the scenario of preleptons of fractional hypercharge is done in a similar way [3]. We just indicate that the topological structure and charge dequantization in preleptons, which are symmetric to the ones in topological quarks, are annulled by the charge normalization procedure leading to leptons with trivial topology and entire charge, as in prequarks (see Eqs. 1 and 2).

6. Presymmetry beyond the Standard Model

We here show figures to clarify some points of presymmetry at the level of the SM. We take the example of proton and its three quarks in Figure 7. For each quark, there is a topological quark. Quarks and topological quarks are different entities. But three topological quarks turn into three quarks via a vacuum tunnelling event, a four-instanton [3]. Quarks and proton have trivial topology and no weak topological charge.

The connection between topological quarks of fractional charge and topologically trivial prequarks of integer charges, and the symmetry between prequarks and leptons, are displayed in Figure 8.

Presymmetry is hidden in the SM with no direct implications to be observed. In fact, it is a pre-dynamical symmetry. Fractional charge is generated in a peculiar manner but only mathematically. Physically, there is nothing new at the level of the SM. Nothing has been altered. This is bad, because one can ask for Occam's razor: "Entities should not be multiplied unnecessary." It is the way science is done! To avoid it, a residual presymmetry in the sense of Ekstein [1, 2] has to be generated. This is one of the motivations to going with presymmetry beyond the SM.

A residual presymmetry requires a doubling of the SM particles. New families must be nonsequential, duplicating gauge groups. Other motivations for the duplication of the SM are to extend presymmetry from matter to forces and extend presymmetry from the electroweak to the strong sector.

Regarding the duplication of the SM, we have been involved in an exotic version [5], where there is an electroweak separation of quarks and leptons as illustrated in Figure 9. Quark and lepton partners are

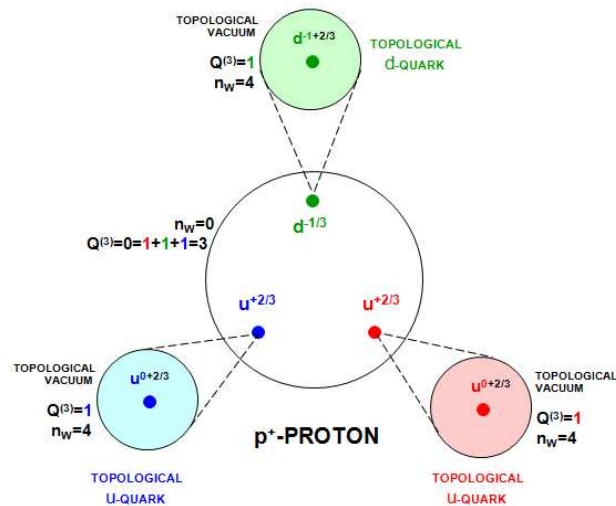


Figure 7: Topological quarks in proton.

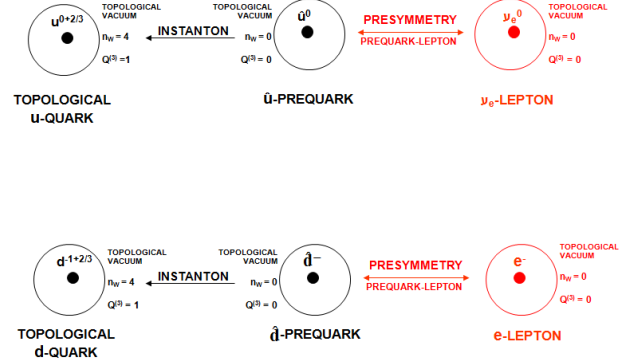


Figure 8: Presymmetry between prequarks and leptons.

denoted by \tilde{q} and $\tilde{\ell}$, respectively.

Under a duplication of the SM, a residual presymmetry is produced as described in Figure 10 [4]. There are two types of presymmetries between prequarks and leptons. They introduce an exotic presymmetry \tilde{P} between prequarks and between leptons. After charge shifts, presymmetries between prequarks and leptons are broken. However, exotic symmetry remains exact in spite of the symmetry-breaking effects. This exotic symmetry can be interpreted as a manifestation of a residual presymmetry in accordance with the idea of Ekstein and its extension from matter to forces. Clearly, particle partners are required to have a residual presymmetry. Its spontaneous breaking occurs because of gauge symmetry breaking according to the pattern

$$\begin{aligned} & [SU(3)_c]^2 \times [SU(2)_L]^2 \times [U(1)_Y]^2 \times \tilde{P} \\ & \quad \downarrow \\ & [SU(3)_c]^2 \times SU(2)_L \times U(1)_Y \\ & \quad \downarrow \\ & [SU(3)_c]^2 \times U(1)_{em}, \end{aligned} \quad (20)$$

which involves a duplication of the Higgs sector [5].

Fermions	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
$\begin{pmatrix} u_{aL} \\ d_{aL} \end{pmatrix}$	3	2	1/3
u_{aR}	3	1	4/3
d_{aR}	3	1	-2/3
$\begin{pmatrix} \tilde{u}_{aL} \\ \tilde{d}_{aL} \end{pmatrix}$	1	2	-1
\tilde{u}_{aR}	1	1	0
\tilde{d}_{aR}	1	1	-2

Fermions	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
$\begin{pmatrix} \tilde{u}_{aL} \\ \tilde{d}_{aL} \end{pmatrix}$	3	2	1/3
\tilde{u}_{aR}	3	1	4/3
\tilde{d}_{aR}	3	1	-2/3
$\begin{pmatrix} \tilde{\nu}_{aL} \\ \tilde{e}_{aL} \end{pmatrix}$	1	2	-1
$\tilde{\nu}_{aR}$	1	1	0
\tilde{e}_{aR}	1	1	-2

Figure 9: Exotic duplication of the SM.

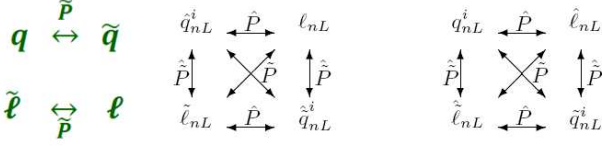


Figure 10: Residual presymmetry under duplication of the SM.

Fermions	SU(3) _c	SU(2) _L	U(1) _Y	Fermions	SU(3) _c	SU(2) _L	U(1) _Y
$\begin{pmatrix} u_{aL} \\ d_{aL} \end{pmatrix}$	3	2	1/3	$\begin{pmatrix} \tilde{u}_{aL} \\ \tilde{d}_{aL} \end{pmatrix}$	3	2	1/3
u_{aR}	3	1	4/3	\tilde{u}_{aR}	3	1	4/3
d_{aR}	3	1	-2/3	\tilde{d}_{aR}	3	1	-2/3
$\begin{pmatrix} \nu_{aL} \\ e_{aL} \end{pmatrix}$	1	2	-1	$\begin{pmatrix} \tilde{\nu}_{aL} \\ \tilde{e}_{aL} \end{pmatrix}$	1	2	-1
ν_{aR}	1	1	0	$\tilde{\nu}_{aR}$	1	1	0
e_{aR}	1	1	-2	\tilde{e}_{aR}	1	1	-2

Figure 11: Hidden copy of the SM.

We are now turning toward a more standard scenario, where there is no electroweak separation of quarks and leptons. It is the hidden version, where all standard particles are neutral with respect to the hidden gauge group. The simplest case is shown in Figure 11, where the duplication of the SM preserves spin and handedness.

The residual presymmetry is produced in a way similar to that of the exotic version. Its breaking is also due to the gauge symmetry breaking, involving duplication of a Higgs sector. This is work in progress and results will be reported elsewhere.

7. Conclusions

Since presymmetry is difficult to be tested at the level of the SM, it may be discarded by using Occam's razor. But presymmetry is also difficult to be refuted. Partner particles with a residual presymmetry are then required to resolve this impasse. The simplest duplication of the SM keeps spin and handedness, extending the residual presymmetry from matter to forces. It is an up-scaled copy of the SM particles which appears nondegenerated about the TeV scale,

much as the second and third generations of quarks and leptons are mere up-scaled copies of the first generation. Everything for presymmetry! Phenomenological implications are similar to those of other popular models such as supersymmetric models with R-parity, little Higgs models with T-parity and universal extra dimension models with KK-parity, which also propose duplication of known particles about the TeV scale.

Presymmetry remains hidden and the model is in trouble if there is no heavy copy of the SM particles. Majorana neutrinos and sequential families, such as a fourth generation, also bring problems to the idea of presymmetry which demands that the number of fermion families and the number of colors be equal. If anything of this could occur, we would go back to the starting point and state that the quark-lepton charge symmetry presented in Figure 2 in support of presymmetry is accidental and not real, which is really hard to be accepted. Hence, our claim is that a simple doubling of the SM particles which pairs separately matter and forces should exist, neutrinos should be of Dirac type and no new sequential family of quarks and leptons should be found.

Finally, we mention that our work has been mostly theoretical. More precise phenomenological analyses on the predicted duplication of the SM particles are necessary. They provide research opportunities.

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